



The two-dimensional finite-difference neutron diffusion programme TVEDIM

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INTRODUCTION

The programme TVEDIM deals with the same problem as the programme TWODIM (ref. 1). They differ mainly in the iterative scheme used for solution of the resulting difference-equations (multiline vs. oneline SOR) and in the discretization-method (interrelation of fluxvalues at mesh-corners and meshcenters, resp.).

At some places the following discussion is cut short, when the material has already been dealt with in ref. 1.

The present report also contains a list of errors in ref.1.

THE PROBLEM

The set of elliptic partial differential equations

$$\begin{aligned}
 - \nabla \cdot (D_g \nabla \phi_g) + \Sigma_{gg} \phi_g + \alpha \Sigma_{p,g} \phi_g = \\
 = \sum_{g' \neq g} \Sigma_{gg'} \phi_{g'} + \lambda X_g \sum_{g'} (v \Sigma_f)_{g'} \phi_{g'} + S_g \\
 (1 \leq g \leq ng), \tag{1}
 \end{aligned}$$

with boundary-conditions

$$- D_g \frac{\partial}{\partial n} \phi_g = \gamma_{gg} \phi_g - \sum_{g' \neq g} \gamma_{gg'} \phi_{g'}, \quad (1 \leq g \leq ng) \tag{2}$$

(note that the off-diagonal terms in the γ -matrix have opposite signs here and in ref. 1) at interfaces between ordinary regions and boundary regions, are considered for 2-dimensional geometries xy , rz , and $r\theta$.

There are 3 types of problems,

- 1) $\lambda = 1/K_{\text{eff}}$ is a criticality-parameter (= eigenvalue)
 $(S_g = \Sigma_{p,g} = 0 \text{ for all } g),$

- 2) α is a criticality-parameter (λ fixed, $S_g = 0$ for all g),
- 3) Source-problem ($S_g \neq 0$ for some g , λ fixed, $\sum_{p,g} = 0$ for all g).

Similar techniques are used for solving these problems.

METHOD OF SOLUTION

The usual mesh-corner 5-point difference equations are solved by a block relaxation procedure in which each block corresponds to a number of consecutive lines in the reactor-model. The line-direction and an upper bound for the number of lines in a block are user-specified. Since, for instance, interior boundary regions are permitted, the actual number of lines in a particular block (this number is found by the programme) may be less.

It is well known that a complete inversion of the group-equations often does not result in the minimal number of outer iterations. Experience shows that the optimal number of lines in a block (often about 5) is usually even less than the maximal number permitted by stability requirements.

TVEDIM is not always faster than TWODIM, in particular not for small, easy problems. But due to its extra parameter, the line-number, it has proved more flexible in use.

In both TWODIM and TVEDIM one inner iteration is performed per outer iteration. The eigenvalue is calculated by means of a neutron-balance. This method is not always locally convergent; i.e. there does not always exist a neighbourhood of the solution, so that convergence can be obtained for an initial flux-vector arbitrarily chosen from this neighbourhood. If the eigenvalue were calculated by a variational expression one would obtain local convergence, and even, with suitable precautions, in the selfadjoint case (one-group-theory) global convergence. In the present case we can linearize relative to the solution to get a criterion for local convergence. The simplest subcase for which an example of divergence does not seem to be known is a one-group problem in one dimension, where the equations are taken in their natural order, and the Jacobi splitting is

used. The existence of a counterexample to the conjecture in ref. 3 would strongly indicate the possibility of divergence for the subcase discussed above, while a proof of the conjecture would constitute a proof of convergence.

INPUT

The following description is partly taken from ref. 2.

The input differs from that for TWODIM (ref. 1) in that it contains specification of linenumber and buckling, and another set of control parameters.

Name of inputfile: d2d1

Name of restart-(disk-)file: tworest

Input-list

<u>Name</u>	<u>type</u>	<u>meaning</u>
<u>problem</u>	<u>integer</u>	<u>problem-number</u>
geom	integer	geometry, 1=xy, 2=rz, 3=rθ
cmx	-	number of material mesh regions in x-direction
cmx	-	- - - - - y -
nbp	-	number of materials ("boundary materials" inclusive)
nb	-	number of boundary materials
ndb	-	- - - - - with γ diagonal
ng	-	number of energy groups
nthg	-	- - thermal groups (possibly with upscattering)
type	-	calculation-type, 1=λ, 2=α, 3=source
nrec	-	number of recalculations (with mesh refinement)
prev	-	if prev>0 initial flux and eigenvalues are read from the disk-file tworest (coarse mesh only). For every abs (prev) iterations eigenvalues and fluxiterate are written on tworest (finest mesh only)
rela	-	direction of lines, 2 = x constant, 3 = y constant
mx	integer	number of regions (finest mesh) for x-direction
my	integer	- - - - - y -
lines	integer	maximal number of lines in a block
xc	array	material mesh x line coordinates
	[0:cmx]	

Name	type	meaning
fm _x	integer array [1:cm _x]	for each material mesh in x-direction number of coarse mesh regions
fac _x	integer array [1:cm _x]	(only for nrec>0) mesh refinement factor for each material mesh in x-direction (applied for each recalculation)
yc	array [0:cm _y]	as xc, but for y-direction; for rθ - geometry θ must be in radians
fm _y	integer array [1:cm _y]	as fm _x , but for y-direction
fac _y	integer array [1:cm _y]	(only for nrec>0); as fac _x , but for y-direction
cpnc	integer array [0:cm _x +1, 0:cm _y +1]	map of material numbers (including interior and exterior boundary materials), each logi- cal record consisting of a row (cm _x +2 numbers), starting with the row corresponding to the last read y-values. Note that a complete rectangular set of numbers must be specified. Those numbers which are meaningless (for instance in case of large internal control areas or corner-regions) should be boundary material numbers. Large elements in the y-matrices give stab- ility problems. However, the "mathematical" boundary-condition: $\phi_g = 0$ for all g, can be obtained by setting the corresponding material number in cpnc equal to zero.
busq	real	buckling; the group absorption + removal crosssections Σ_{gg} are modified by addition of $D_g * busq$.
f	integer	format-indicator for the following multi- group-coefficients: 1=6el2,5, otherwise free format

The following set of records specifies data for each material. As regards notation see eq. (1).

name	type	meaning
k	integer	material number or 0; what data are expected after this, depends on k
gad	array [1:ng]	diagonal γ -matrix (for $0 < k \leq \text{ndb}$)
gam	array [1:ng, 1:ng]	γ -matrix (for $\text{ndb} < k \leq \text{nb}$)
dd	array [1:ng]	D_g
ss	array [1:ng, 1:ng]	$\Sigma_{g,g'}$
fs	array [1:ng]	χ_g
nsf	-	$(\nu \Sigma_f)_g$
rr	-	reactionrate-(usually fission-) cross sections (see sample output)
pp	-	(only for type $\neq 1$) for type = 2: $\Sigma_{p,g}$ for type = 3: S_g
kb	integer	For material numbers $m \in [kb, ke]$
ke	-	(k=0 only) the data are set equal to those just read

(for $\text{nb} < k \leq \text{nep}$)

The number of non-zero k-values plus the sum of the numbers (ke-kb+1) must equal ncp.

The following control-variables (rm to kappa incl., not epsm) have default-values, obtained, if the input-value is negative. They are given in parentheses in the following list.

name	type	meaning
rm	integer	maximal iteration number (50)
eps	real	the iterations stop, when the maximal estimated error in a flux-coordinate is less than eps times maximal flux (0.0005)
epsm	-	if epsm>0 omega will be adjusted (only in combination with an extrapolation) to maximise estimated convergence-rate.
epse	-	the calculated extrapolation - factors must agree within epse (relative error) for three consecutive iterations, before extrapolation is attempted (0.1)
omega	array [0:nrec]	relaxation factors (1.2)
lamb	real	$\lambda = 1/K_{\text{eff}}$ (1)
alfa	-	α (1)
kappa	-	$\kappa =$ upper bound for α (1)
printer	integer	for printer<2 no proper output. For 2<printer<9 flux- and reactionrate-distributions are printed, while for printer <u>></u> 9 the print-out contains also progress-report for the iterations.

If not all reaction-rate crosssections are zero then for each calculation (nrec + 1 times in all) the following set of input parameters must be specified:

name	type	meaning
powerout	integer	powerout <-2 gives no reaction-rateprint-out; if powerout = -1 the reaction-rate-distribution is calculated and printed for the earlier specified grid (initially the coarse grid); if powerout = -2 a new grid must be specified (see below)

name	type	meaning
facxp	integer (for powerout=-2) array [0:mx]	mx is the number of regions in the current mesh; facxp[n]=1 means that x-interface-line number n+1 in the current mesh shall also be an interface-line in the reaction-rate-grid
facyp	integer (for powerout = -2) array [0:my]	as facxp (mutatis mutandis)

Output

As seen in the sample-output the input is printed immediately after it has been read.

The amount of output is governed by the input-parameter printer, as described above, and may contain progress-report for the iterations, flux- and reaction-rate-(usually power-density-) tables.

REFERENCES

1. C.K. Kristiansen, "The finite-difference neutron diffusion programme TWODIM", Risø-M-1891 (1976).
2. C.K. Kristiansen, Risø, Denmark, unpublished work (1973)
3. C.K. Kristiansen, "A matrix convergence problem", problem 77-14^x, SIAM Review, to appear.

LIST OF ERRORS IN PEF. 1

- 1) p. 7, line 5 from bottom, should read,
rela integer direction of lines in SLOR,
2 = x constant, 3 = y constant
- 2) p. 11, top, the first 8 lines should be replaced by,
If not all reaction-rate-crosssections are zero, then for
each calculation (nrec + 1 lines in all) the following set of
input parameters must be specified:

<u>name</u>	<u>type</u>	<u>meaning</u>
powerout	integer	powerout < -2 gives no reaction-rate-printout; if powerout = -1 the reaction-rate-distribution

PROBLEM

GEOM 1 CMX 3. 3. 5. 2. 1. 2. 1. 1. 1. 0. 2.
 MX 16. MY 16.

16 LINES

XC 0. 6.000E+00 7.000E+00 8.000E+00
 FMX 6. 1. 1.

FACK 2. 2. 2.

YC 0. 6.000E+00 7.000E+00 8.000E+00
 FMY 6. 1. 1.

FACY 2. 2. 2.

COMPOSITION NUMBERS
 1. 2. 2. 2.
 1. 3. 3. 3.
 1. 5. 6. 3.
 1. 4. 5. 3.
 1. 1. 1. 1.

COMPOSITIONS
 BUSJ: 3.
 EFORMAT= 0

1 EXTPL: 0. 0.

2 GA4: 2.000E-01 0. 1.000E-01 5.000E-02

3 0: 2.000E+00 3.000E-01
 SS: 3.000E-02 0. 3.000E-02 1.000E-02
 FS: 1.000E+00 0.
 NSF: 0. 0.
 RR/SF: 0. 0.

4 0: 1.000E+00 4.000E-01
 SS: 2.000E-02 0. 1.000E-02 1.000E-02
 FS: 1.000E+00 0.
 NSF: 0. 5.000E-02
 RR/SF: 0. 2.000E-02

0 5 6

TVEDIM sample output

```

      RM      EPS      EPSM      EPSF
      50      1.0E-04      .      1.0E-01
OMEGA:      1.50      1.50
      LAMB      ALPHA      KAPPA
      1.00E+00      1.00E+00      1.00E+00
PRINTER= 10.
KEFF CALCULATION
ITNO      RESIDUAL      RATIO      LAMBDA      KEFF
1      1.733878603E+00      1.000000000E+00      1.172276416E+00      8.530404398E-01
2      1.579275901E+00      -4.846089574E-01      1.333727744E+00      7.497782072E-01
3      7.522351041E-01      -8.233984932E-01      7.435753704E-01      1.059685324E+00
4      5.095560821E-01      -8.781647522E-01      1.169602714E+00      8.549911757E-01
5      2.857998105E-01      1.000000000E+00      1.035993232E+00      9.143357475E-01

6      1.300184513E-01      -5.431477361E-01      1.094157275E+00      9.139448073E-01
7      6.424162070E-02      -5.143905851E-01      1.070288513E+00      9.343275097E-01
8      3.575044318E-02      -4.602297673E-01      1.079425295E+00      9.272179533E-01
EXTRAPOLATION FACTOR = 6.7567E-01 RELAXATION FACTOR = 1.5000E+00
9      6.715932700E-03      1.000000000E+00      1.075976911E+00      9.293379731E-01
10     1.595110171E-03      -2.172915582E-01      1.076534177E+00      9.299048767E-01
11     3.289359447E-04      -2.297120824E-01      1.076535131E+00      9.289100534E-01
12     5.340489213E-04      -5.626710127E-01      1.076577336E+00      9.288596380E-01
13     3.027712718E-04      -6.451204027E-01      1.076518434E+00      9.289204611E-01

```

COMPOSITION NUMBERS

7500.	3.	3.	3.	3.	3.	3.	3.	3.
6500.	5.	5.	5.	5.	5.	5.	5.	5.
5500.	4.	4.	4.	4.	4.	4.	4.	4.
4500.	4.	4.	4.	4.	4.	4.	4.	4.
3500.	4.	4.	4.	4.	4.	4.	4.	4.
2500.	4.	4.	4.	4.	4.	4.	4.	4.
1500.	4.	4.	4.	4.	4.	4.	4.	4.
500.	4.	4.	4.	4.	4.	4.	4.	4.

---- x 500.1500.2500.3500.4500.5500.6500.7500.

FLUX	GROUP 1.
8000.	5250.5213.5131.4916.4658.4333.3957.3565.3230.
7000.	5851.5810.5697.5460.5132.4825.4390.3920.3565.
6000.	7070.7021.6872.6622.6265.5791.5133.4390.3957.
5000.	1031.7975.7804.7513.7074.6530.5791.4825.4333.
4000.	8773.8715.8520.8197.7728.7094.6265.5192.4658.
3000.	9323.9251.9051.8703.8197.7513.6622.5480.4916.
2000.	9703.9632.9417.9051.8520.7804.6872.5687.5131.
1000.	9926.9853.9632.9255.8710.7975.7021.5810.5213.
0.	9999.9926.9703.9323.8773.8031.7070.5851.5250.

---- x 0.1000.2000.3000.4000.5000.6000.7000.8000.

FLUX	GROUP 2.
8000.	9638.9604.9511.9381.9153.8870.8440.7895.7176.
7000.	9431.9397.9327.9216.9075.8916.8756.8613.8426.
6000.	9249.9222.9174.9152.9031.8935.8799.8756.8630.
5000.	9151.9147.9107.9047.8979.8913.8836.8716.8630.
4000.	9133.9121.9097.9050.8986.8979.8931.8907.8863.
3000.	9135.9121.9105.9075.9050.9047.9032.9016.8961.
2000.	9150.9145.9126.9105.9075.9075.9174.9327.9511.
1000.	9153.9157.9147.9127.9122.9147.9227.9397.9604.
0.	9158.9161.9157.9155.9153.9161.9246.9421.9630.

---- x 0.1000.2000.3000.4000.5000.6000.7000.8000.

Let $\varphi_k^{(i)}$ be coordinate k of flux-iterate i ,

$$\|\varphi\|_\infty = \max_k |\varphi_k|, \text{ and } \|\varphi\|_1 = \sum_k |\varphi_k|.$$

Then

$$\text{residual}^{(i)} = \frac{\|\varphi^{(i)} - \varphi^{(i-1)}\|_\infty}{\|\varphi^{(i)}\|_\infty},$$

$$\text{ratio}^{(i)} = \frac{\|\varphi^{(i)} - \varphi^{(i-1)}\|_1}{\|\varphi^{(i-1)} - \varphi^{(i-2)}\|_1} \cdot \text{sign} \left(\frac{\varphi_2^{(i)} - \varphi_2^{(i-1)}}{\varphi_2^{(i-1)} - \varphi_2^{(i-2)}} \right),$$

$$\text{where } |\varphi_2^{(i-1)} - \varphi_2^{(i-2)}| = \|\varphi^{(i-1)} - \varphi^{(i-2)}\|_\infty.$$

For $\text{ratio}^{(i)} \rightarrow \text{mys}$ we have

$$\text{extrapolation factor} = 1/(1 - \text{mys}).$$

REACTANT RATE SENSITIVITY

Y
I
I
I
AVERAGE 10000

7000.	5116	5001	4891	2401
5000.	10069	10068	9959	9836
3000.	10078	10080	9942	9031
1000.	10087	10038	10069	5116

-----X 1000. 3000. 5000. 7000.
EL.TIME= 13.2 PRG.TIME= 6.0 I/O.TIME= 1.5

ITNO	RESIDUAL	RATIO	LAMBDA	KEFF
1	7.251003333E-01	1.000000000E+00	1.095843364E+00	9.125391754E-01
2	5.314177184E-01	1.111111111E+00	1.089134123E+00	9.179019910E-01
3	2.750280259E-01	5.000000000E+00	1.082530407E+00	9.237515812E-01
4	1.699834086E-01	5.000000000E+00	1.077659306E+00	9.279370525E-01
5	1.340050471E-01	5.000000000E+00	1.073338399E+00	9.316252232E-01
6	6.423786700E-02	5.000000000E+00	1.077330144E+00	9.332412981E-01
7	4.000811334E-02	4.000000000E+00	1.076679295E+00	9.287316733E-01
8	1.913421050E-02	1.000000000E+00	1.079418071E+00	9.272333906E-01
9	1.403768833E-02	1.000000000E+00	1.079075393E+00	9.275779074E-01
10	8.920355223E-03	1.000000000E+00	1.073198495E+00	9.274747260E-01
11	4.921497570E-03	1.000000000E+00	1.077898683E+00	9.277309789E-01
12	3.304547823E-03	4.000000000E+00	1.077893902E+00	9.277350935E-01
13	1.439769633E-03	4.000000000E+00	1.077821546E+00	9.277373737E-01
14	3.553007723E-04	1.000000000E+00	1.077871620E+00	9.277342717E-01
15	7.840655584E-05	1.000000000E+00	1.077869783E+00	9.277358433E-01
16	3.518015583E-05	1.000000000E+00	1.077826117E+00	9.277371874E-01
17	1.371940661E-05	1.000000000E+00	1.077838064E+00	9.277401183E-01

COMPC POSITION NIMD

7750.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.
7250.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.
6750.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.
6250.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.
5750.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.
5250.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.
4750.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.
4250.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.
3750.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.
3250.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.
2750.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.
2250.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.
1750.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.
1250.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.
750.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.
250.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.

---- x 250. 750. 1250. 1750. 2250. 2750. 3250. 3750. 4250. 4750. 5250. 5750. 6250. 6750. 7250. 7750.

FLUX

Y
I

GROUP 1.

8000.	5239.5222.5202.5155.5090.5007.4905.4785.4647.4492.4322.4140.3945.3755.3569.3396.3231.
7500.	5120.5010.4881.4732.4564.4376.4158.3942.3696.3433.3153.2859.2544.2215.1875.1526.
7000.	5041.4871.4600.4349.4076.3784.3470.3135.2782.2415.2038.1651.1254.837.3918.3747.3569.
6500.	6438.6476.6442.6383.6306.6204.6078.5928.5755.5557.5334.5086.4810.4501.4146.3947.3755.
6000.	7034.7051.7014.6953.6866.6754.6616.6451.6259.6038.5787.5502.5179.4910.4379.4154.3949.
5500.	7575.7562.7522.7456.7362.7241.7092.6912.6703.6460.6182.5864.5502.5086.4604.4359.4160.
5000.	8027.8013.7971.7900.7800.7670.7510.7318.7091.6829.6527.6182.5787.5334.4815.4553.4322.
4500.	8424.8410.8365.8290.8194.8047.7877.7672.7431.7151.6829.6460.6038.5557.5008.4733.4492.
4000.	8771.8755.8704.8629.8516.8374.8175.7983.7726.7431.7091.6703.6259.5755.5182.4896.4647.

3500.	9039.9053.9004.8922.8826.8656.8459.8245.7990.7672.7318.6913.6451.5928.5336.5042.4785.
3000.	9322.9305.9255.9170.9050.8895.8702.8469.8195.7877.7510.7092.6616.6078.5470.5168.4905.
2500.	9533.9515.9463.9375.9253.9093.8895.8656.8374.8047.7671.7241.6754.6204.5584.5276.5007.
2000.	9722.9693.9632.9543.9417.9253.9050.8806.8518.8184.7800.7362.6866.6306.5677.5364.5090.
1500.	9833.9815.9763.9671.9543.9375.9175.8936.8628.8260.7800.7355.6853.6306.5749.5432.5153.
1000.	9926.9907.9853.9781.9632.9463.9255.9004.8708.8365.7971.7522.7015.6442.5900.5481.5202.
500.	9991.9962.9917.9845.9685.9515.9305.9053.8755.8410.8013.7562.7051.6476.5931.5510.5230.
0.	9999.9981.9926.9853.9702.9533.9322.9069.8771.8425.8027.7575.7064.6488.5841.5520.5239.

--- X 0. 500. 1000. 1500. 2000. 2500. 3000. 3500. 4000. 4500. 5000. 5500. 6000. 6500. 7000. 7500. 8000.

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GROUP 2.

8000.	9132.9124.9111.9051.8957.8830.8677.8494.8280.8047.7788.7504.7179.6852.6425.6294.6156.
7500.	9544.9537.9516.9482.9444.9374.9273.9122.8933.8707.8437.8137.7831.7528.7194.6828.6525.
7000.	9412.9406.9388.9358.9318.9267.9197.9140.9066.8989.8909.8829.8752.8678.8610.8525.8425.
6500.	9309.9303.9298.9262.9227.9183.9132.9074.9012.8944.8863.8781.8703.8621.8552.8478.8394.
6000.	9234.9229.9218.9193.9163.9135.9093.9031.8972.8931.8878.8831.8791.8763.8752.8731.8679.
5500.	9162.9178.9166.9147.9120.9089.9050.9010.8957.8926.8887.8854.8831.8821.8829.8834.8804.
5000.	9138.9145.9134.9117.9095.9057.9035.9001.8957.8925.8897.8887.8877.8873.8909.8937.8928.
4500.	9129.9125.9116.9102.9082.9057.9032.9004.8977.8953.8935.8926.8926.8948.8989.9037.9047.
4000.	9119.9117.9109.9096.9079.9059.9037.9015.8994.8977.8957.8967.9001.9012.9066.9133.9160.
3500.	9118.9115.9108.9097.9083.9065.9048.9030.9015.9004.9001.9009.9032.9074.9140.9222.9264.
3000.	9121.9119.9113.9103.9091.9075.9061.9048.9037.9032.9035.9050.9091.9131.9207.9303.9357.
2500.	9127.9126.9120.9112.9101.9087.9076.9060.9059.9053.9067.9089.9125.9183.9267.9374.9439.
2000.	9135.9133.9128.9121.9111.9101.9091.9083.9079.9082.9094.9124.9163.9227.9318.9434.9507.
1500.	9142.9140.9136.9129.9121.9112.9103.9097.9096.9102.9117.9146.9191.9262.9358.9481.9561.
1000.	9148.9146.9142.9135.9128.9120.9113.9109.9109.9116.9134.9166.9216.9298.9388.9516.9600.
500.	9152.9150.9146.9140.9133.9126.9119.9115.9117.9125.9145.9178.9225.9303.9406.9537.9624.
0.	9153.9152.9148.9142.9135.9127.9121.9114.9110.9120.9148.9181.9234.9309.9412.9544.9632.

--- X 0. 500. 1000. 1500. 2000. 2500. 3000. 3500. 4000. 4500. 5000. 5500. 6000. 6500. 7000. 7500. 8000.

REACTION RATE DENSITY

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AVERAGE 10000

7000.	5115	5031	4897	2472
5000.	10069	9961	4925	4897
3000.	10038	9934	9051	5031
1000.	10068	10038	10059	5115

----- X 1000. 3000. 5000. 7000.
EL.TIME= 61.0 PROC.TIME= 33.0 I/O.TIME= 3.2